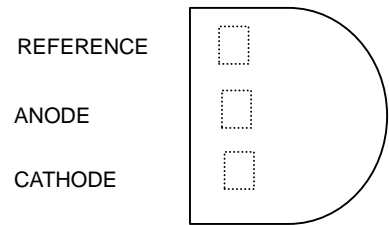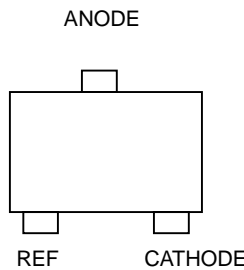The TL431 integrated circuits are three-terminal programmable shunt regulator diodes. These monolithic IC voltage references operate as a low temperature coefficient zener which is programmable from Vref to 36 volts with two external resistors. This device exhibits a wide operating current range of 1.0 to 100 mA with a typical dynamic impedance of $0.22\,\Omega$. The characteristics of these references make them excellent replacements for zener diodes in many applications such as digital voltmeters, power supplies, and op amp circuitry. The 2.5 volt reference makes it convenient to obtain a stable reference from 5.0 volt logic supplies, and since the TL431 operates as a shunt regulator, it can be used as either a positive or negative voltage reference
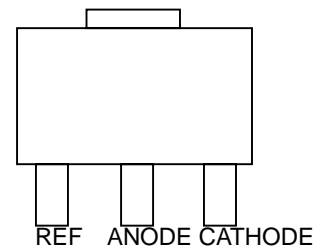
FEATURE

1. Programmable Output Voltage to 36 Volts
2. Low Dynamic Output Impedance,$0.22\,\Omega$ Typical
3. Sink Current Capability of 1.0 to 100mA
4. Equivalent Full-Range Temperature Coefficient of 50ppm/℃ Typical
5. Temperature Compensated for Operation over Full Rated Operating Temperature Range
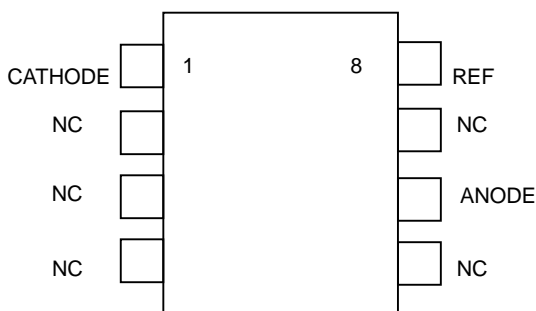6. Low Output Noise Voltage

REFERENCE

ANODE

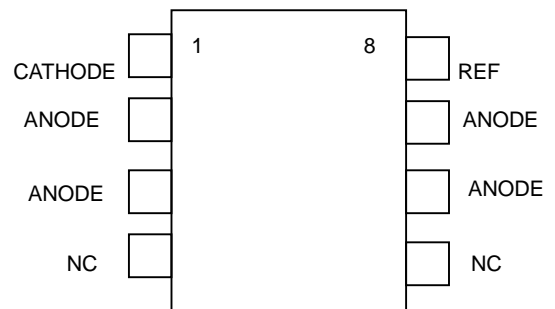CATHODE

TO-92 TOP VIEW

ANODE

REF   CATHODE

SOT-23 TOP VIEW

REF   ANODE CATHODE

SOT-89 TOP VIEW

CATHODE	1	8	REF
NC			NC
NC			ANODE
NC			NC

DIP-8 TOP VIEW

CATHODE	1	8	REF
ANODE			ANODE
ANODE			ANODE
NC			NC

SOP-8 TOP VIEW

● **BLOCK DIAGRAM**

SYMBOL

Representative Block Diagram
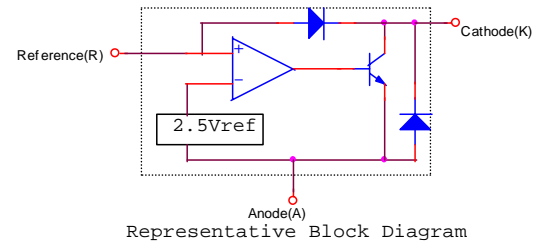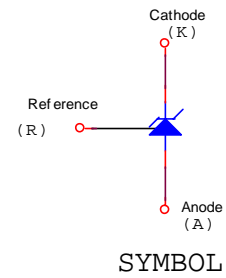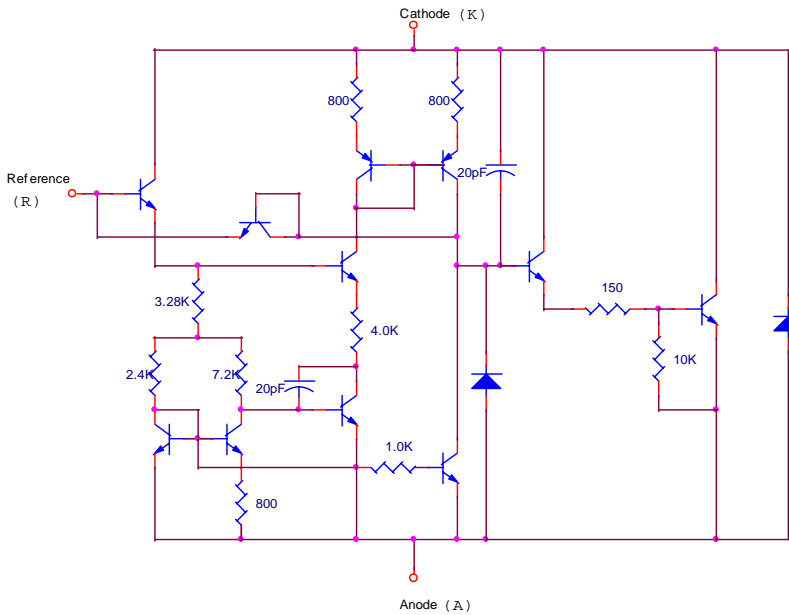
● **ABSOLUTE MAXIMUM RATINGS**

(Full operating ambient temperature range applies, unless otherwise noted)

Rating	Symbol	Value	Unit
Cathode To Anode Voltage	V_{KA}	37	V
Cathode Current Range, Continuous	I_K	-100 to +150	mA
Reference Input Current Range, Continuous	I_{ref}	-0.05 to +10	mA
Operating Junction Temperature	T_J	150	℃
Operating Ambient Temperature Range TL431CT/CP/CD/CH/CLT1	T_A	-20 ~ +85	℃
Storage temperature Range	T_{stg}	-65 to +150	℃
Total Power Dissipation @T_A=25℃ Derate above 25℃ Ambient Temperature T,D Suffix Package P Suffix Package H Suffix Package LT1 Suffix Package	P_D	0.70 1.10 1.0 0.28	W

Total Power Dissipation @T$_C$=25℃			
Derate above 25℃ Case Temperature			
T,D Suffix Package	P$_D$	1.5	W
P Suffix Package		3.0	
H Suffix Package			
LT1 Suffix Package			

● **THERMAL CHARACTERISTICS**

Characteristics	Symbol	T,D Suffix	P Suffix	H Suffix	LT1 Suffix	Unit
Thermal Resistance, Junction to Ambient	R$_{\theta JA}$	178	114	110	575	℃/W
Thermal Resistance, Junction to Case	R$_{\theta JC}$	83	41	8	150	℃/W

● **RECOMMENDED OPERATING CONDITIONS**

Condition/Value	Symbol	Min	Max	Unit
Cathode to Anode Voltage	V$_{KA}$	V$_{ref}$	36	V
Cathode Current	I$_K$	1.0	100	mA

● **ELECTRICAL CHARACTERISTICS**(Ambient temperature at 25℃ unless otherwise noted)

Characteristic	Symbol	TL431			Unit
		Min	Typ	Max	
Reference Input Voltage (Fig 1)					
V$_{KA}$=V$_{ref}$, I$_K$=10mA					
T$_A$=+25℃ Tolerance 0.5%	V$_{ref}$	2.483		2.507	V
1%		2.470	2.495	2.520	
2%		2.445		2.55	
T$_A$=T$_{low}$ to T$_{high}$ (Note 1)		2.453	--	2.537	
Reference Input Voltage Deviation Over					
Temperature Range (Fig 1, Note 1,2)	$\triangle$V$_{ref}$	--	3.0	17	mV
V$_{KA}$=V$_{ref}$. I$_K$=10mA					
Ratio of Change in Reference Input Voltage					
To Change in Cathode to Anode Voltage	$\dfrac{\triangle V_{ref}}{\triangle V_{KA}}$				mV/V
I$_K$=10mA (Figure 2), $\triangle$V$_{KA}$=10V to V$_{ref}$		--	-1.4	-2.7	
$\triangle$V$_{KA}$=36V to 10V		--	-1.0	-2.0	

Reference Input Current (Figure 2) I_K=10mA, R1=10k, R2=∞ T_A=+25℃ $T_A=T_{low}$ to T_{high} (Note 1)	I_{ref}	-- --	1.8 --	4.0 5.2	μA
Reference Input Current Deviation Over Temperature Range (Figure 2, Note 1) I_K=10mA, R1=10k, R2=∞	$\triangle I_{ref}$	--	0.4	1.2	μA
Minimum Cathode Current for Regulation $V_{KA}=V_{ref}$ (Figure 1)	I_{min}	--	0.5	1.0	mA
Off-State Cathode Current (Figure 3) V_{KA}=36V, V_{ref} =0V	I_{off}	--	260	1000	nA
Dynamic Impedance (Figure 1, Note 3) $V_{KA}=V_{ref}$, $\triangle I_K$=1.0mA to 100mA, f≤ 1.0kHz	$|Z_{KA}|$	--	0.22	0.5	Ω

1

T_{low}=0℃, T_{high}=+70℃

2

The deviation parameter $\triangle V_{ref}$ is defined as the differences between the maximum and minimum values obtained over the full operating ambient temperature range the applies.

$$\Delta V_{ref} = V_{ref} \, max - V_{ref} \, min$$
$$\Delta T_A = T_2 - T_1$$
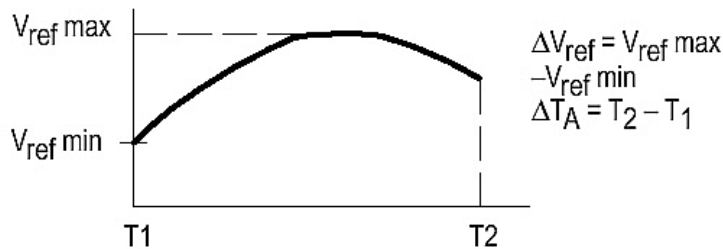
The average temperature coefficient of the reference input voltage, αV_{ref}, is defined as:

$$\alpha V_{ref} \frac{ppm}{°C} = \frac{\frac{\Delta V_{ref}}{V_{ref} \, @ \, 25°C} \times 10^6}{\Delta T_A} = \frac{\Delta V_{ref} \times 10^6}{\Delta T_A (V_{ref} \, @ \, 25°C)}$$

αV_{ref} can be positive or negative depending on whether V_{ref} Min of V_{ref} Max occurs at the lower ambient temperature. (Refer to Figure 6)

Example: $\triangle V_{ref}$ =8.0mV and slope is positive, V_{ref} @25℃=2.495V, $\triangle T_A$=70℃

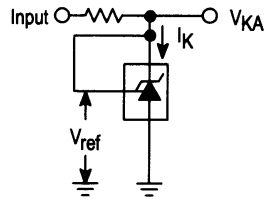$$\alpha V_{ref} = \frac{0.008 \times 10^6}{70(2.495)} = 45.8 \text{ ppm/℃}$$

3

The dynamic impedance Z_{KA} is defined as:
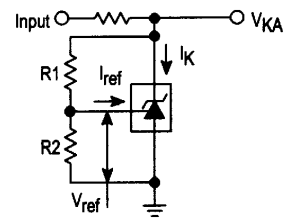
$$| Z_{KA} | = \frac{\Delta V_{KA}}{\Delta I_K}$$

When the device is programmed with two external resistors, R1 and r2, (refer to Figure 2) the total dynamic impedance of the circuit is defined as:

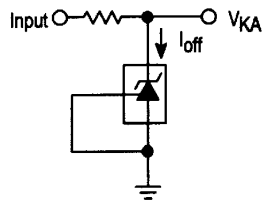$$| Z_{KA}' | \approx | Z_{KA} | (1 + \frac{R1}{R2})$$

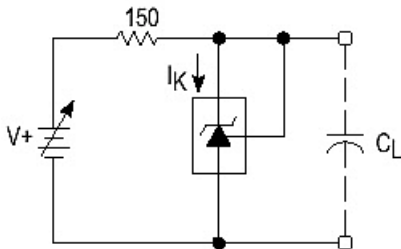● **TEST CIRCUITS**

Fig 1.Test Circuit for V$_{KA}$=V$_{ref}$

$$V_{KA} = V_{ref}(1+\frac{R1}{R2})+ I_{ref} \cdot R1$$

Fig 2.Test Circuit for V$_{KA}$>V$_{ref}$

Fig 3.Test Circuit for I$_{off}$

● **APPLICATION EXAMPLE**

Fig 4.Test circuit for curves A of stability boundary conditions
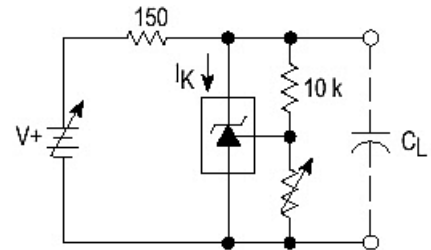
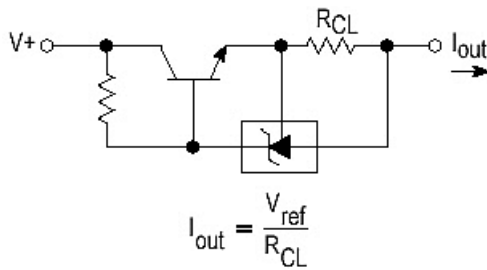**Fig 5.Test circuit for curves B.C and D of stability boundary conditions**

$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$
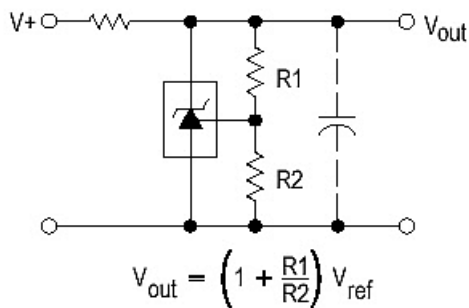
Fig 6.Shunt regulator

$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$
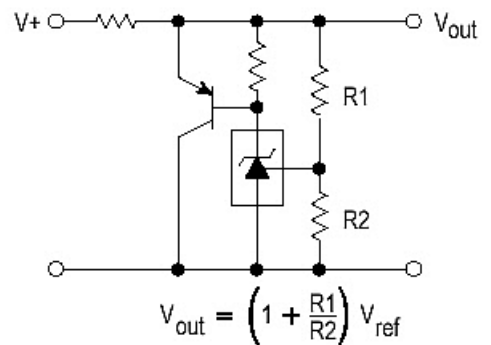
Fig 7.High current shunt regulator

$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

$$V_{out} \, min = V_{ref} + 5.0V$$
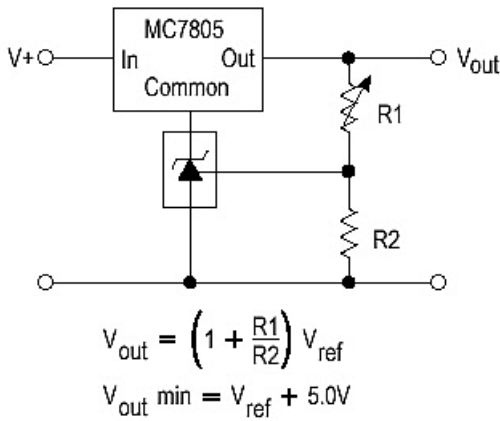
Fig 8. Output control of a three-Terminal fixed regulator

$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

$$V_{out} \, min = V_{ref} + V_{be}$$
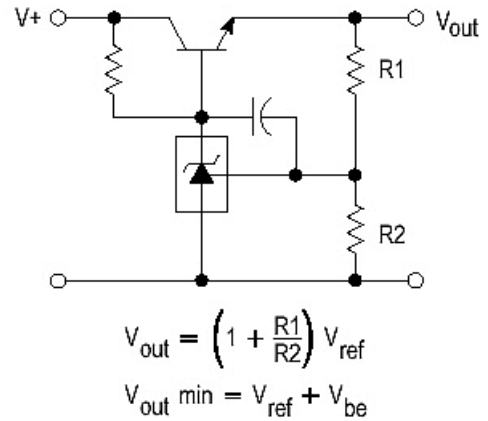
Fig 9. Series pass regulator

$$I_{out} = \frac{V_{ref}}{R_{CL}}$$

Fig 10 .Constant current source

$$I_{Sink} = \frac{V_{ref}}{R_S}$$
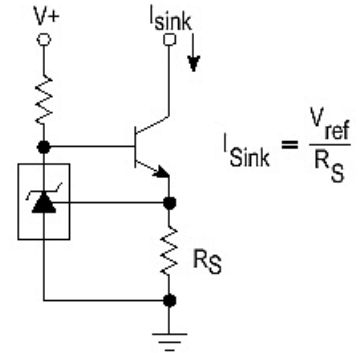
Fig 11 .Constant current sink

$$V_{out(trip)} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

Fig 12 .Triac crowbar

$$V_{out(trip)} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

Fig 13.SCR crowbar

2001-05-A

L.E.D. indicator is 'on' when V+ is between the upper and lower limits.
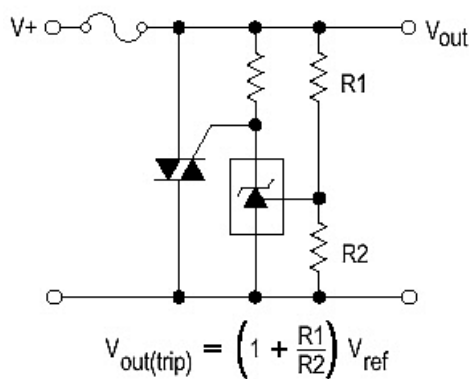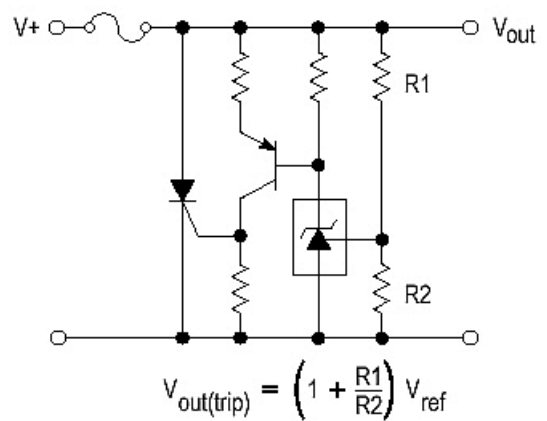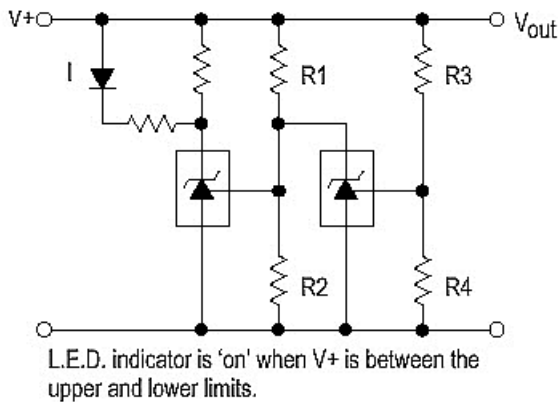
$$\text{Upper Limit} = \left(1 + \frac{R3}{R4}\right) V_{ref} \quad \text{Lower Limit} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

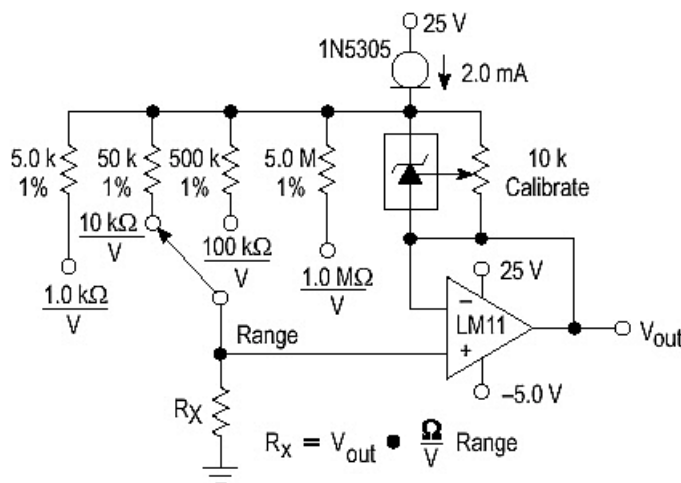| V_{in}	V_{out}
< V_{ref}	V+
> V_{ref}	≈ 2.0 V

$V_{th} = V_{ref}$

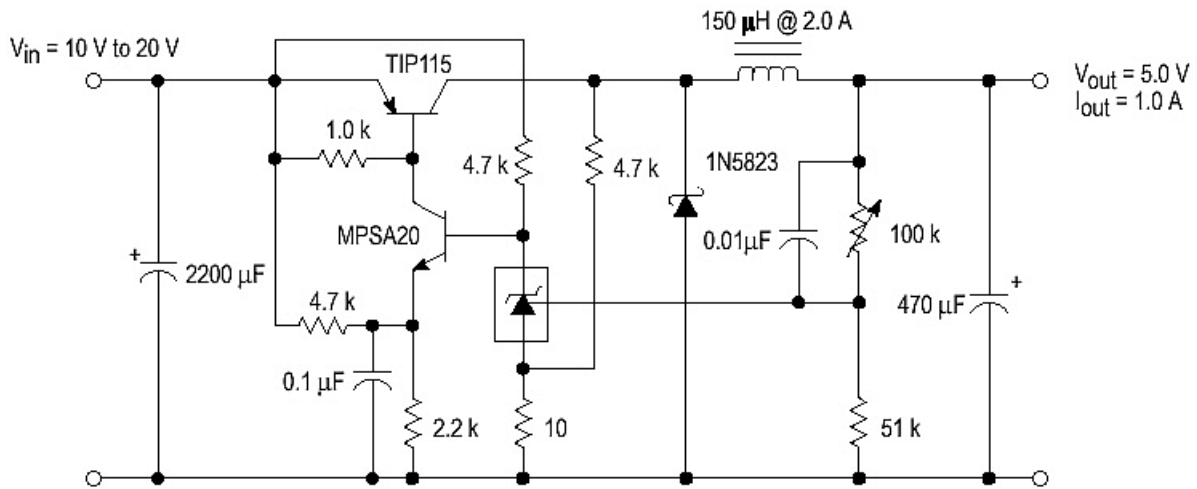**Fig 14.Voltage monitor** **Fig 15 . Single-supply comparator with temperature-compensated threshold**
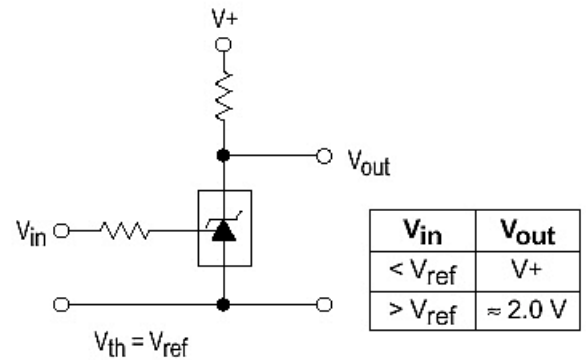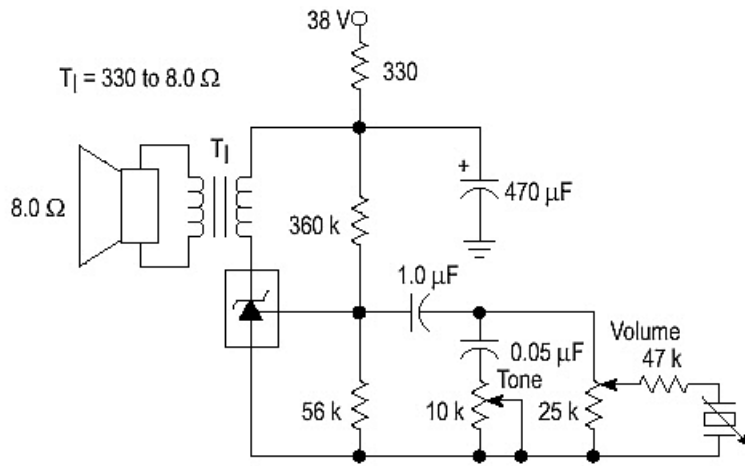
Fig 16 .Simple 400mW phone amplifier

$$R_X = V_{out} \bullet \frac{\Omega}{V} \text{ Range}$$

Fig 17.Liner ohmmeter

Test	Conditions	Results
Line Regulation	V_{in}=10V to 20V,I_o=1.0A	53mV (1.1%)
Load Regulation	V_{in}=15V ,I_o=0A to 1.0A	25mV (0.5%)
Output Ripple	V_{in}=10V ,I_o=1.0A	50mV$_{PP}$ P.A.R.D
Output Ripple	V_{in}=20V,I_o=1.0A	100mV$_{PP}$ P.A.R.D
Efficiency	V_{in}=15V,I_o=1.0A	82%

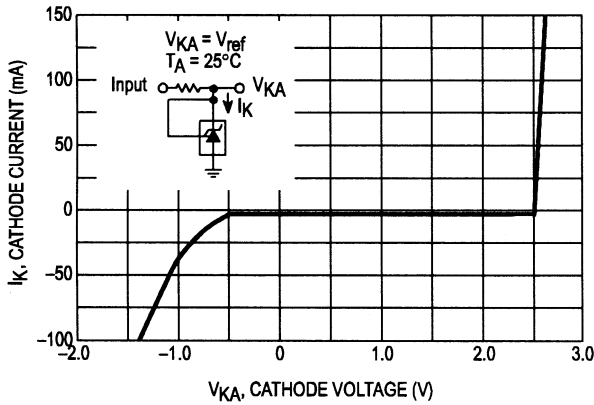**Fig 18.High efficiency step-down switching converter**

● **ELECTRICAL CHARACTERISTICS CURVES**

Fig 19.Cathode current versus cathode voltage
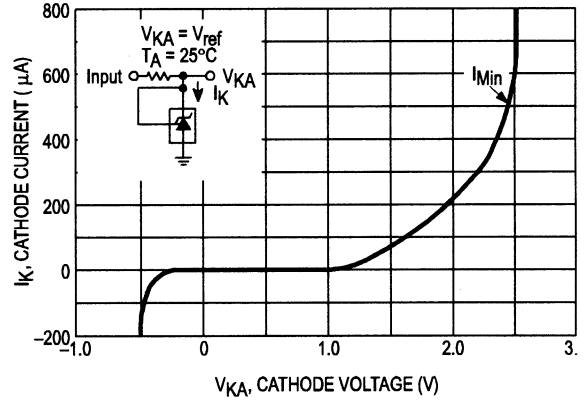
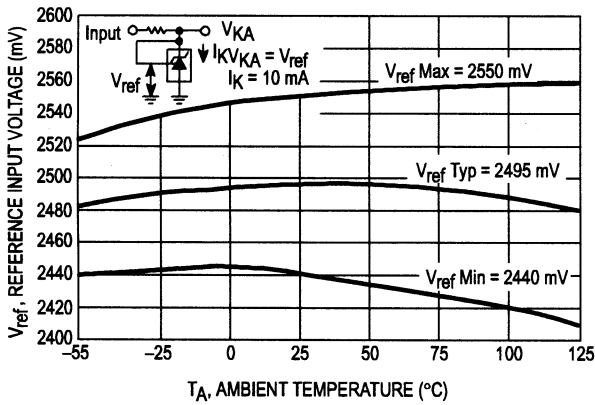**Fig 20.Cathode current versus cathode voltage**

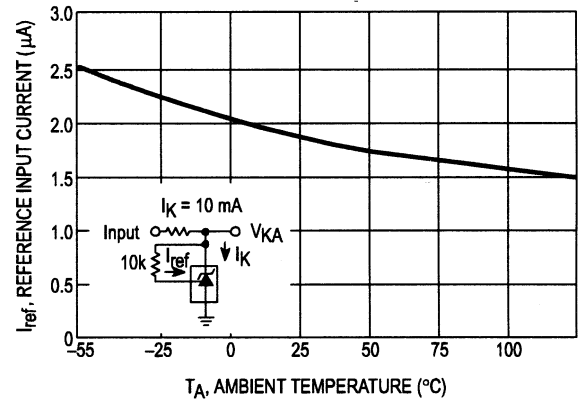**Fig 21.Reference input voltage versus ambient temperature**

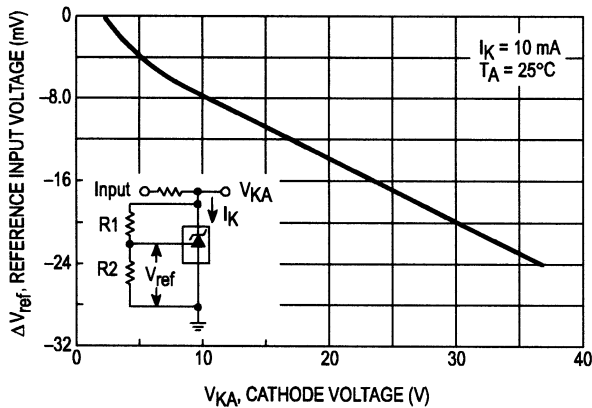**Fig 22.Reference input current versus ambient temperature**

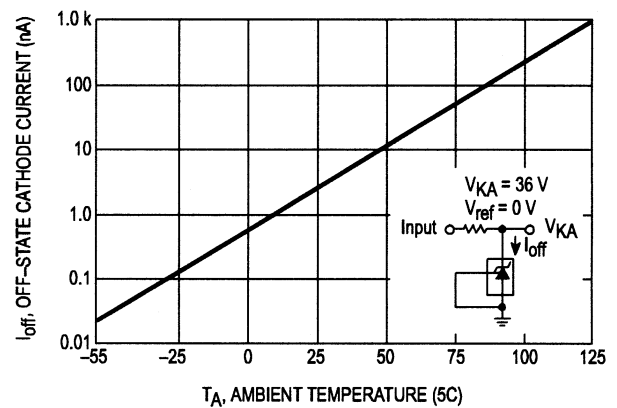**Fig 23.Change in reference input voltage versus Cathode voltage**

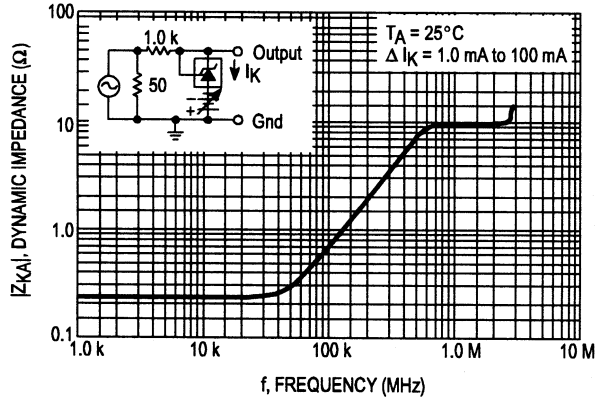**Fig 24. Off state cathode current versus ambient temperature**

2001-05-A

Fig 25. Dynamic impedance versus frequency
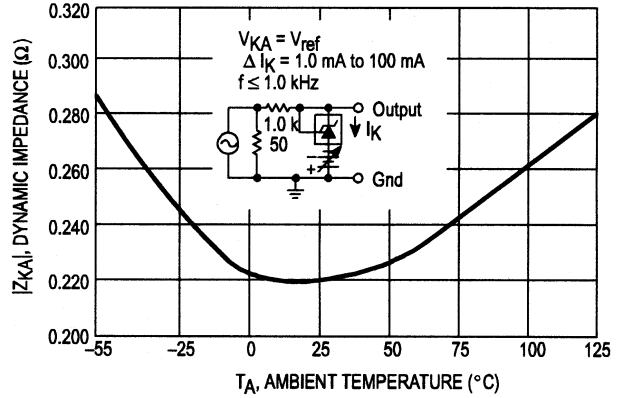

Fig 26.Dynamic impedance versus ambient temperature
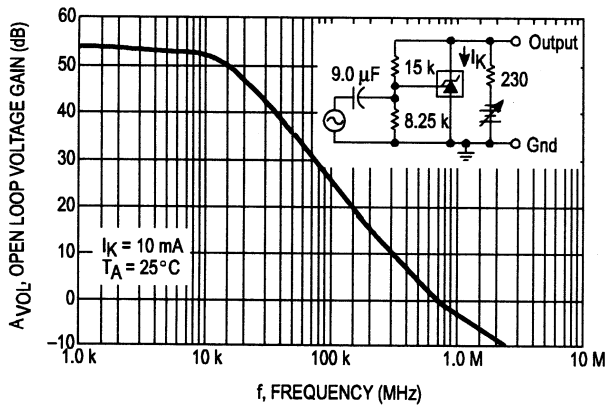

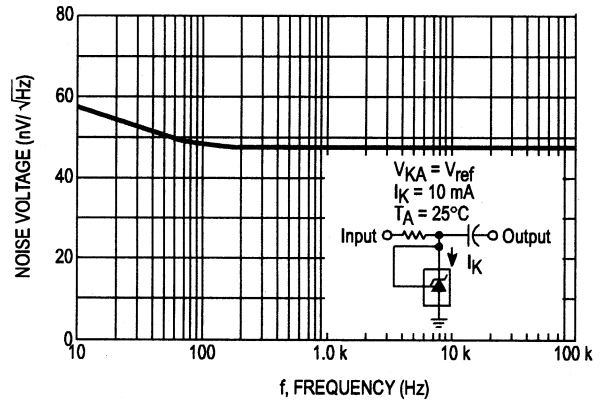**Fig 27. Open loop voltage gain versus frequency**

Fig 28. Spectral noise density

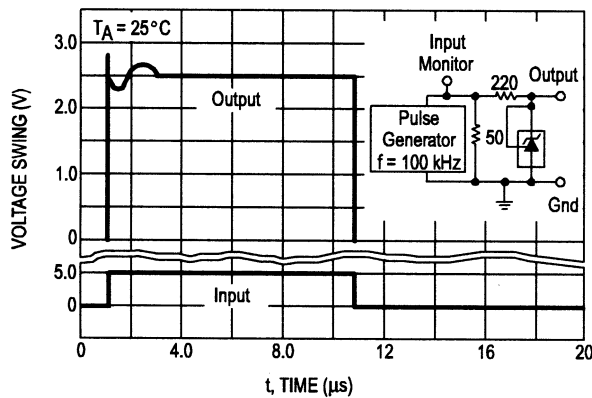**Fig 29. Pulse response**
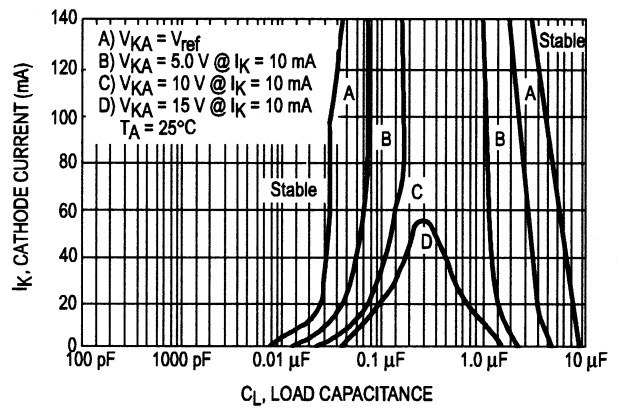
Fig 30. Stability boundary conditions

ORDER INFORMATION

DEVICE	TEMPERATURE RANGE	PACKAGE
TL431BCT 0.5%	-20~+85℃	TO-92
TL431ACT 1%	-20~+85℃	TO-92
TL431CT 2%	-20~+85℃	TO-92
TL431BCP 0.5%	-20~+85℃	DIP-8
TL431ACP 1%	-20~+85℃	DIP-8
TL431CP 2%	-20~+85℃	DIP-8
TL431BCD 0.5%	-20~+85℃	SOP-8
TL431ACD 1%	-20~+85℃	SOP-8
TL431CD 2%	-20~+85℃	SOP-8
TL431BCLT1 0.5%	-20~+85℃	SOT-23
TL431ACLT1 1%	-20~+85℃	SOT-23
TL431CLT1 2%	-20~+85℃	SOT-23
TL431BCH 0.5%	-20~+85℃	SOT-89
TL431ACH 1%	-20~+85℃	SOT-89
TL431CH 2%	-20~+85℃	SOT-89

2001-05-A